THE
DESCRIPTION and *USE*
Of a New Invented

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POCKET REFLECTING MICROSCOPE,
WITH A
MICROMETER.

The POWER of MAGNIFYING by this *Microſcope*, and the uſe of the *Micrometer* in MEASURING ſmall Objects therein, made plain and eaſy by CALCULATIONS.

The Method of adapting this Microſcope into a WALKING-CANE, or WHIP.

The Deſcription of an UNIVERSAL MICROSCOPE; or the Method of mounting the Microſcope on a BALL and SOCKET that renders it of univerſal Uſe.

The DOUBLE MICROMETER deſcribed, and its Uſe in the univerſal Microſcope explained.

The way of computing the *Power of Magnifying* in TELESCOPES, and of meaſuring the Heavenly Bodies by the *Double Micrometer*, fitted thereto.

Inſtructions for rightly uſing the *Microſcope*, *Teleſcope*, *&c.*

The whole illuſtrated with *Copper-Plate Figures.*

By BENJ. MARTIN.

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BRITISH MUSEUM

THE PREFACE.

THE *Microſcope* is doubtleſs a noble invention, and great improvement have been made therein at ſundry times: But as almoſt all human contrivances, or works of art, arrive to their perfection by very ſlow advances, ſo I conceive the Microſcope according to any of its preſent forms or methods of uſing it, is capable of much farther improvement.

I hope I have made this appear in the ſequel of this ſmall Tract; I have ſhewn how its uſe may be rendered more common and eaſy by a new Pocket Form. I have alſo ſhewn a way of mounting a Microſcope on a *Ball and Socket* that renders it of univerſal uſe.

I have applied the Micrometer ſingle and double, to the Microſcope, ſhewn how objects are thereby meaſured both in Microſcopes and Teleſcopes to an extreme degree and exactneſs; and, laſtly, I have given neceſſary inſtructions for the uſe of theſe inſtruments in a proper manner.

So excellent, curious and entertaining

an inſtrument as the Microſcope could never have continued ſo long a rarity, or in ſo few hands, had not the forms, in which they have hitherto been made, occaſioned them to be ſold at great prices, and confined their uſe *within doors*.

'Tis true there is a pocket Microſcope in Uſe, but the price is ſo great, the way of uſing it ſo difficult and tedious, (beſides, that it is a ſingle one,) as renders it of little conſequence to any but Gentlemen of fortune and leiſure.

On the contrary, the pocket microſcope I here propoſe, is not only a double reflecting one, but is moſt eaſy to be uſed, beſides the *Micrometer* which is peculiar to itſelf; and yet withal, ſo ſimple is its Structure, that the purchaſe thereof is within the reach of common people's pockets.

Were it poſſible for perſons to be convinc'd of the wonderful variety, the amazing forms, the ſurprizing richneſs, beauty, and glory of the inviſible part of the world, which nature has only permitted us the ſight of by means of the microſcope, they would be ſo far from wanting to be courted to the uſe of it, that they would never by any means be reſtrained therefrom.

With what ardour do men generally purſue any invention or contrivance which promiſes pleaſure or delight? How ready to proſtitute every ſenſe to objects that can afford gratifications even of the meanneſt ſort! With what ſubmiſſion are we ever inclin'd to accept of meer animal Senſations when they can but produce the leaſt tranſports of Senſe! would men, therefore, contentedly diſregard or be ignorant of the *Microſcope*, the ſource of the moſt refined, genuine, and tranſporting pleaſures both of ſenſe and reaſon, could they be but once appriſed of it? This would argue them ſtrangely prepoſterous, and capable of a greater depravity than can poſſibly be derived from original Sin.

And if to the pleaſure which naturally and infallibly attends the uſe thereof, be added the conſideration of the great advantage, yea abſolute neceſſity, of the knowledge attainable by this inſtrument alone, its uſe will appear univerſal and neceſſary.

With what grace can any one pretend to skill in *Philoſophy*, who is unacquainted with a microſcope? is not this the Clue by which he is conducted thro' the dark, untrodden, mazy paths of nature? is not this the artificial organ of ſight, by which he diſcerns the magnitude, figure, parts and texture, of far the greateſt, far the more curious part of nature's workmanſhip?

Again with reſpect to the *Natural Hiſtorian*, who would buy or read his hiſtory of Animals, Plants, Minerals, &c. that is not imbelliſhed and improved by the diſcoveries of the Microſcope?

The *Divine*, above other men, is oblig'd to be converſant with the microſcope; what others *may* do from curioſity and amuſement, he *ought* to do from duty, in this reſpect. Is he not concerned to ſtudy and learn the nature and perfections of God from the works of his hands? Becauſe that which may be known of God, is made manifeſt to them, for God hath ſhewed it unto them, by the diſcovery of the Microſcope. For the inviſible things of him from the creation of the world are clearly ſeen thereby; and from thence are more eminently underſtood and diſplayed, the Attributes of his eternal power, and infinite wiſdom. How are *Commentaries* on the Bible bought up, though they often explain away the ſenſe, or give one more ambiguous; while the *microſcope* remains neglected, tho' it alone reveals and ſets in their native light, the recluſe and hidden myſteries contained in the great book of Nature!

Time would fail me to ſpecify the infinite particulars in which the microſcope would be of uſe to the *Phyſician*, the *Chemiſt*, and the *Apothecary*, in giving them a more intimate knowledge of *drugs*, medicines, &c. And to be ſhort, I can't help thinking that, whereever the *Eye* is neceſſary, the *Microſcope* is alſo, which is but an improvement of the *natural ſight*.

'Tis true there are many people on whom one if not both their eyes are ill beſtowed, and it would be as rational to recommend or urge the uſe of a microſcope to an *owl*, or any *nocturnal* animal, as to them.

Had *Ariſtotle* known the uſe of this inſtrument, what a prodigy would he have been in his time! and had *Solomon* been bleſt with the wiſdom derived from the *viſual Science*, he would have wrote of Plants, whoſe exiguity would far more exceed the *Hyſſop's* on the wall, than the *Hyſſop's* does the *Cedar's* in *Lebanon*. To go a ſtep higher, what pleaſures muſt *Eden* have afforded *Adam* could he have enjoy'd it with a Microſcope! Had I been there, I fancy I ſhould have had a much greater temptation to have encreaſed my knowledge by viewing the fruit of the tree of knowledge with this inſtrument than by eating it; which would, by the way, have been no tranſgreſſion: what *Paradiſe* of pleaſure can compare with that where luxuriant nature gratifies the eye with a rich variety of attire, forms, and colouring in every flower and plant, and this not only in the larger leaves and branches, but in the moſt minute, and unſeen parts of each !

The *Indies* afford no animals ſo richly variegated with party-colours ; ſo ſecured within native coats of mail, jemmar'd and emboſs'd ; ſo various and wonderful in their forms and parts ; and ſo terribly armed with weapons for defence or hoſtile attacks, as the Microſcope has diſcovered in theſe our northern climes.

By the Microſcope we know that the uſe of *Feathers* is not the property of birds alone, nor *ſcales*, of the finny Tribe. Infine, by the Microſcope we diſcover an amazing community, harmony, variety and contrariety of Beings, life, ſenſe, motion, &c. in all the orders and ſpecies of the animal and vegetable creation.

In the next place, what ſatisfaction and pleaſure muſt it raiſe to an inquiſitive and rational mind to be acquainted with the wondrous ſmallneſs of the indiſcernable tribes of Animalcules, by means of the *Micrometer*? to meaſure the living moveable points in moſt ſorts of water ; the ſlender *Anguiculæ*, or Eels in vinegar, and other liquids ; the *Mites* in cheeſe or meal ; the Diameters of fleſhy fibres, of the particles of fat, of the meal or *farina* of flowers, of ſalts extracted from plants, blood, &c. of the pearly drops or exudations on the leaves of Aromatic Plants; with the Antennæ or Feelers, the *Proboſcis* or trunk, the eyes, legs, claws, wings, ſtings, &c. of inſects and reptiles? with innumerable other curious and delicate ſubjects to be found in all the *Miniature of Nature*.

Advertiſement,

THESE *Pocket Reflecting Microſcopes* are made and ſold by the Author in *Chicheſter*; thoſe with a *Micrometer* at the Price of *one Guinea*; without the *Micrometer*, at 12 s. 6d. a Piece. Alſo the beſt Double Reflecting Microſcopes with a *Micrometer* at 2 l. 12 s. 6d. without, at 2 l. 2 s. Alſo *Teleſcopes*, with or without *Micrometers*; *Scioptric-Balls* for Dark-Chambers; and any other Optical Inſtruments at the loweſt Prices.

N. B. This *Pocket-Microſcope*, &c. ſhall be carefully ſent from *London* to any part of *England*, by a Letter of Order to me at *Chicheſter*, directing to what Carrier, &c. it ſhould be delivered.

Juſt Publiſhed,

The PHILOSOPHICAL GRAMMAR; with large Notes, and the Addition of ten new Copper Plates; the Second Edition.

LONDON:
Printed for *J. Noon* at the *White-Hart* in *Cheapſide*, near *Mercer's Chapel.*

A DESCRIPTION of the POCKET REFLECTING MICROSCOPE.

THIS Microſcope contains all the eſſential parts of ſuch an inſtrument in the moſt compendious and portable Form, which is, for the moſt part, new; and the moſt commodious for uſe of any yet invented. It is furniſhed with a Micrometer for meaſuring ſmall objects, or their ſmaller parts, to a very great Degree of Nicety and Exactneſs; as will be ſhewn hereafter.

This Microſcope and its Micrometer appear when in uſe as repreſented in Fig. 1. where,

A, is the Braſs Top next the Eye.

B, the Sliding Piece drawn out, to give an Aperture for viewing the object.

C, The part (generally of wood) which ſcrews off to let in the Eye-Glaſs.

D, The part which contains the Eye-Glaſs in the *Screw*-part above.

E, The part which contains the Micrometer, and is half an inch wide.

F, The inner Table or Drawer fixed into the Head-part of the Microſcope and ſliding up and down in

G, the outer Tube or Caſe of the Microſcope, wherein

H, H, H, is an Aperture or opening on the fore part for the free admiſſion of Light into the lower part of the Microſcope.

I, is the Pipe or ſmall wooden Tube ſcrew'd into the Bottom of the inner part F.

K, is the Button or Cell which is ſcrew'd on to the ſaid Pipe, and contains the object-Glaſs.

L, is an Aperture in the back part of the Microſcope for the paſſage of

M, A Glaſs Tube containing a ſubject (ſuppoſe an *Eft*) for viewing the Circulation of the Blood, &c.

N N, a long narrow Aperture for a long ſlip or plate of Glaſs to paſs thro'.

O O, A circular piece of Glaſs fitted into the Bottom of the Microſcope on which objects, whether opake or pellucid, may be view'd.

P, A concave Mirrour fitted into

Q Q, a circular Lid or Foot which moves by a ſmall Hinge on the back-part of the Microſcope at the Bottom; by means of which any Degrees of Light may be reflected on the object to be viewed.

Theſe are the ſeveral parts of this Microſcope which appear to view when we are uſing it; when it is not in uſe, the inner Tube F is ſlid down upon the external Caſe G; the Door H H is ſhut; and the Foot Q Q is alſo cloſely ſhut up upon the bottom of the Microſcope, which then is of a cylindric form from Q to E 4 inches and a half; the remainder from E to A is 1 inch and a half; the whole being but 6 inches in length, and about 1 and a half Diameter, it muſt be allowed that nothing can be contrived more *portable* or fit for *Pocket-uſe*.

The other parts of the Microſcope not viſible to the Eye while the inſtrument remains entire, are repreſented in Fig. H, which is a perpendicular Section of the Microſcope thro' its Axis; and are as follow.

A, an Object-Glaſs, or ſmall Lens, contain'd in the Button K.

B C, an Eye-Glaſs, being a double Convex, whoſe *Focus* is at the Diſtance of one Inch.

D E, The image of the object made by the ſmall Lens A, at the Diſtance of an inch from the Eye-Glaſs B C, that is, in its *Focus*.

F G H, The Micrometer, ſharp pointed at F.

G, the Screw-part thereof.

H I, the Hand or Index which moving

round the graduated Circle on the outſide ſhews the meaſure of an object in the equal parts of an inch propoſed.

Such are the conſtituent parts of this ſmall Microſcope, both external and internal; from whence it is eaſy to conceive, that as its Structure is moſt ſimple, ſo its Uſe is moſt extenſive and eaſy; and its Effects as great as any can poſſibly be with regard to magnifying objects, as I ſhall now ſhew.

Of the POWER of MAGNIFYING Objects by this MICROSCOPE.

THE apparent Magnitude of an object is meaſured by the the Angle under which it appears to the Eye; that is, an object is apparently larger or ſmaller, as the Angle form'd by Lines drawn from each extremity and terminating in the Eye is greater or leſſer.

Alſo this Angle is greater or leſſer according as the object is nearer or farther ſituated from the Eye; and in very ſmall objects, the magnitude of theſe Angles may be eſteemed reciprocally proportional to the diſtances from the Eye; that is, if any ſmall object be placed at firſt at the Diſtance of 1 Foot, and then at the Diſtance of 3 Feet;

its apparent Magnitude will in the firſt Caſe be 3 times greater than in the latter.

We muſt further underſtand that a glaſs Lens does only magnify the *Apparent Bulk* of Bodies; and that, by rendering them diſtinctly viſible at a nearer diſtance to the Eye; for the Eye cannot diſtinctly view an Object at a Diſtance leſs than 6 inches; if then I take a Lens, whoſe Focal Diſtance is but 1 inch, this Lens held cloſe to the Eye will render the object diſtinctly viſible at the Diſtance of one inch, and therefore will appear ſix times as large as when view'd by the naked Eye at the Diſtance of 6 inches.

In this Microſcope there are two object-Glaſſes, the Focal Diſtance of one is 37 hundreth parts of an inch, and of the other 66 hundredth parts of an inch.

Suppoſed the firſt be uſed, and it is required to have the image E D of the object K at the Diſtance of 4 inches from the Lens A, and 10 times larger than the object; in this Caſe the object K muſt be placed 4 tenths of an inch from A. Now the Apparent Magnitude of the object K at the Diſtance A K 4 tenths, will be to the ſame at the diſtance of 6 inches, as 6 is to 4 tenths, or as 60 to 4, that is, as 15 to 1. So that the apparent Magnitude of the object by this Lens is 15 times greater than by the naked Eye.

Again as the object K and its image E D

appear of an equal Magnitude from A, or are ſeen under equal Angles; if we take another Lens B C, whoſe focal diſtance is 1 inch, and view the image E D thro' it at the diſtance C L 1 inch, then it is plain the magnitude of the image ſeen thro' B C will be 4 times greater than that which appears thro' A, becauſe the diſtance A L is 4 times greater than C L. Wherefore the apparent magnitude of the object K through the eye-glaſs B C will be 4 times 15, that is, 60 times greater than when viewed by the naked eye at the diſtance of 6 inches.

The object hitherto conſidered I have ſuppoſed to be a *Line*, or the length or breadth of any ſurface: But if we regard the ſuperficies of any object, that will be magnified in a *duplicate* proportion of a Line, that is, according to the *Square* thereof; therefore ſince a Line is magnifyed 60 times, the ſurface of an object will be magnified 60 times 60, or 3600 times; that is, the ſurface of any object will appear *three thouſand and ſix hundred* times greater by this Microſcope than to the bare eye.

Laſtly, if we regard the *Solidity* of an object, that will be magnified in a *triplicate* proportion of a Line, or according to the *Cube* thereof. Thus the *Solidity* or whole Bulk of an object, will in this Microſcope, appear 60 times 60 times 60, or 216000, that is, *two hundred and ſixteen thouſand* *times* greater than to the eye itſelf, at ſix inches diſtance.

As this power of magnifying is extremely great, ſo it can be only uſeful for extremely ſmall objects, *viz.* ſuch as appear but points, or are wholly inviſible to the naked eye; for larger objects the other object-glaſs is more proper; the Focus of which being 66 hundredth parts of an inch, will there render the object viſible.

If the object K be placed at the diſtance of 8 tenths of an inch (which is double the former) from this Lens at A, it will form an object at E D half as big as the former, and the apparent magnitude of a Line by this Lens at 8 tenths of an inch diſtance will be to that by the eye at 6 inches diſtance, as 6 to 8 tenths, or as 60 to 8, that is as 7 and a half to 1. This magnitude will be encreaſed 4 times by the eye-glaſs B C; conſequently the magnitude of a Line will be 4 times 7 and a half, that is, 30 times greater in this Caſe than by the naked eye. Now ſince the ſquare of 30 is 900, and the cube 27000; therefore the true magnitude of the ſurface of an object will be encreas'd 900 times; and the ſolidity thereof 27000 times, which I preſume is enough for any objects in general.

Theſe two object glaſſes I take to be ſufficient for any purpoſes; tho' as many others may be uſed as deſired.

Of the MICROMETER and its USE in meaſuring Minute Objects in the MICROSCOPE.

THE Micrometer H F, which I have here adapted to the Microſcope, is about the ſize of a large needle, finely tapering to a point at F. G is the Screw-Part, which contains juſt 50 threads in an inch, and is about half an inch in length. This is mov'd by the finger on the index H I, in the center of a braſs plate which on its extremity hath a circle divided into 10 equal parts, and each of theſe ſubdivided into two others, ſo that the whole circle has twenty equal parts or diviſions. All which is ſo evident in the figures of the Plate, and ſo eaſy to be underſtood, that nothing more can be neceſſary in the deſcriptive part.

I ſhall now ſhew the excellent uſe of the Micrometer in taking the Dimenſions of the ſmalleſt bodies to the greateſt degree of exactneſs deſirable: in order to this we ſhall ſuppoſe the ſmalleſt object Lens to be uſed, *viz.* that whoſe focus is at the diſtance of 37 hundredth parts of an inch. It has been already ſaid, that if an object K be placed at the diſtance of 4 tenths of an inch from this Lens at A, it will form an image thereof at E D, diſtant from A 4 inches; which becauſe it is juſt 10 times as great as the diſtance A K; therefore the image E D will be 10 times as large as the object K. If then the object K be one tenth of an inch long, the length of the image E D will be juſt one inch.

Again, ſince the Micrometer has juſt 50 threads in an inch, if we ſuppoſe the point F juſt touching the image in E, and then the index turn'd 50 times round, the point of the Micrometer will be ſeen to move preciſely over the length of the image from E to D, as being juſt the ſpace of one inch. Hence one turn of the index is one fiftieth part of an inch in the image, and 1 fiftieth part of one tenth, that is, it will be one five hundredth part of an inch in the object: Laſtly, ſince the ſaid index is moved over a circle of 20 equal parts, the motion over one of thoſe parts will meaſure the one twentieth of one five hundredth part of an inch, that is, the point of the micrometer will move over a ſpace which will be the one ten thouſandth part of an inch in the object; this I preſume is a degree of nicety and exactneſs ſufficient for any purpoſes of this kind.

I shall now give an example of the uſe of the micrometer. Suppoſe you would meaſure the eye of any inſect; proceed as follows. (1.) Turn the index round ſo often that it may be at a convenient diſtance from the plate or face of the micrometer.

(2.) Set

(2) Set the index to the beginning of the diviſion on the circle, viz. at ten. (3.) Having laid the inſect on a ſlip of glaſs move it backwards and forwards thro' the hole N N under the object lens, till the point F of the micrometer ſhall juſt touch the extremity of the eye on one ſide. (4.) Then holding the microſcope ſteady turn the index about with your finger till you ſee the point of the micrometer exactly over the extremity of the eye on the oppoſite ſide. (5.) Laſtly, count how many whole revolutions, and parts of another, the index has made in the time; and then turn them into the parts of an inch, thus;

Suppoſe the motion of the index were 7 revolutions, and an half, or ten parts; then ſince every revolution contains 20 ten thouſandth parts of an inch, 7 revolutions will contain 140, and the other ten parts added make 150, *viz.* a hundred and fifty ten thouſandth parts, or fifteen thouſandth parts of an inch; that is, the width of the eye is 15 of ſuch equal parts as an inch contains a thouſand.

After the ſame manner you proceed to meaſure the length or breadth of any other ſmall object; and knowing that, it is eaſy to find what part of an *inch ſquare* the *ſuperficies* of that object is; or what part of a *cubic inch* is contained in the *whole bulk* of the object by a ſmall skill in common menſuration.

Hence it appears how eaſy 'tis to make a calculation of the ſurprizing *Number*, *Minuteneſs*, &c. of microſcopic objects, and their ſeveral parts; and that with greater certainty by this inſtrument, than can be attained to in the meaſurement of the largeſt bodies by any of the common methods in uſe. 'Tis to be hop'd therefore that this will take place, for the time to come, of the poor way of making uncertain computations from random conjectures, and gueſſings at things in the dark; they raiſe our wonder and admiration indeed, but cannot tell us certainly at what! the *Micrometer* will ſhew 'tis preſum'd, much more exactly by its index how many of the cuticular glands, particles of fat, fibres of the muſcles, animalculæ in water, &c. are contained in an inch, either in *length*, *ſquare* or *cubic*, than Monſr. *Lewenhoek*'s famous meaſure, a *Grain of Sand*.

Note, if the larger object Lens be uſed, the image E D being but 5 times as large as the object K, and every diviſion on the micrometer being the thouſandth part of an inch, thoſe diviſions will in this caſe be only the five thouſandth parts of an inch in the object, viz. half of what they were before when the image was twice as large, or ten times larger than the object.

Of the method of Adapting this MICROSCOPE in a WALKING-CANE or WHIP.

IT is nothing new to hear of a *Teleſcope* in a *Cane*, but no one has hitherto attempted to adapt a microſcope to that moſt common handy inſtrument; tho' the occaſions or opportunities of uſing a *Microſcope* offer much more frequently to a Gentleman in his walk, than they do for the uſe of a *Teleſcope*. A perſon can ſcarce look or tread beſides innumerable *Microſcopic Objects*, whereas we are often obliged to walk a great way for *Teleſcopic Ones*. All nature abounds with the former, but is very ſparing in the latter.

Now 'tis evident from a view of the faſhion of this *New reflecting Microſcope*, that nothing is eaſier than to fit it into the Head part of a walking Cane, in the manner as repreſented in Fig. III: where I H K L is the upper part of a Cane, which being made hollow to a proper depth receives in the manner of a caſe the ſmall microſcope A G B F E in an inverted poſition. The part A G B is the foot of the microſcope containing the reflecting mirrour, and ſhuts cloſe upon the lower part thereof; on the part A B is a ſcrew by which means it ſcrews into the Cane at H I; ſo that the *Foot* of the microſcope G makes the *Head* of the Cane. All which is plain and eaſy to be apprehended from a bare view of the Figure.

There can be no objection to the uſe of the microſcope in this way, unleſs a perſon unacquainted with the nature of this inſtrument, ſhould ſuppoſe the body of this microſcope too ſmall for the purpoſe of magnifying. But he will ſoon be convinced of the error in this ſuppoſition, when he conſiders that they are only the ſmalleſt bodies, or parts of bodies, which are the ſubjects of the microſcope; and laſtly, that only that part of the image which lies under the middle part of the Eye Glaſs can be diſtinctly ſeen. The degree and reaſon of magnifying does not depend on the *Size* or *Bulk* of the microſcope, or on the diameter of the glaſſes, but on the *Convexity* and *Diſpoſition* of thoſe glaſſes with reſpect to one another in the ſtructure of this inſtrument. A ſmall microſcope ſhall magnify an object equally with a larger, provided the glaſſes have the ſame diſtance of focus's and poſition in each.

I ſhall now ſhew what I judge to be the ſize and ſtructure of a microſcope proper for a Cane, as follows; viz. if the cane be large it may receive a microſcope one inch in diameter from outſide to outſide, as is that in the figure. But if the Cane be ſmaller the tube may be eight tenths of an inch diameter, which is as ſmall as can be neceſſary.

The inner part draws out at W N and the eye glaſs is placed at C D: if now the focal diſtance of the object glaſs at O be forty three hundredth parts of an inch, and it be placed half an inch from the object at P it will form an image at Q R, 3 inches diſtant from O. Suppoſe alſo the diſtance from Q R to C D be three fourths of an inch, equal to the focal diſtance of the eye glaſs at C D.

Then for the power of magnifying, ſince the diſtance O P or half an inch, is to ſix inches as 1 to 12, therefore the object ſhall appear twelve times larger by the glaſs at O than by the bare eye at 6 inches diſtance. Again, ſince the diſtance from O to Q R is to the diſtance from Q R to C D as three to three fourths, or as four to one, therefore the image or object will be ſeen four times as large by the eye-glaſs at C D as by the Lens at O. Conſequently the *length* of the object will be magnified in this microſcope four times twelve, that is forty eight times, the ſurface 48 times 48, that is, 2304 times; and the bulk or ſolidity 48 times 48 times 48, viz. 110592 times.

If the eye-glaſs hath its focal diſtance 1 inch, then will the *length* of an object be magnified 3 times 12, or 36 times; the *Sur-*

face 1296 times; (for that is the ſquare of 36.) and the *ſolid Content* 46656 times, ſince that is the cube of 36. Which is enough in all reaſon.

Then with reſpect to meaſuring the object by the *Micrometer*, ſince every ſmall diviſion on the circle is the 1000dth part of an inch, and the image is 6 times the length of the object, (becauſe the diſtance C N is 6 times greater than O P; therefore the motion of the index over one of theſe diviſions will meaſure a length that is the 6000dth part of an inch in the object. Alſo, one of the larger, or tenth diviſions will be the 3000dth part; half a revolution of the index a 600th part, and a whole one the 300dth part of an inch; and ſo on in proportion for any number and parts of a revolution.

The Microſcope, therefore, in this form, is eaſy to be accommodated within a *Cane*, and is ſufficient to anſwer all the purpoſes of *magnifying* and *meaſuring* ſmall objects; eſpecially the former, without any kind of trouble or impediment to walking.

This Microſcope may with the ſame eaſe and convenience be adapted within the hand part of an *Horſe-Whip*, and will in this caſe be found very ſerviceable to Gentlemen who ride much, or long journeys.

There are other ways in which the form of this Microſcope renders it applicable, which Gentlemen may differently propoſe, and practiſe as they think fit.

But I ſhall now proceed to give ſome account of another method of uſing the Microſcope, for ſuch purpoſes as the forms hitherto invented will not permit.

The UNIVERSAL MICROSCOPE; or a new Method of Mounting the MICROSCOPE for viewing and meaſuring of Objects in any Situation or Poſition whatſoever. Alſo an Account of the DOUBLE MICROMETER to be uſed with the DOUBLE MICROSCOPE.

THE uſual conſtruction of the Microſcope and its Frame is ſuch as confines it to the view of one ſort of objects only, and to one only poſition of them, which is that *below* the Microſcope. But as there is frequent occaſion for one, who would obſerve nature in all her operations and effects, to view every part of her workmanſhip great and ſmall, and in every poſition or ſituation whatſoever without conſtraint or incumbrance, ſo it is neceſſary to have a new way of mounting this machine that ſhall permit its uſe to be with perfect freedom and liberty; and ſuch I ſhall propoſe the *mounting of it on a BALL and SOCKET* in ſuch a manner as repreſented in Fig. IV. Of which take the following deſcription and account.

A, is the top of the Microſcope.

B, C, the upper and lower eye-glaſſes.

D, the part where the double Micrometer E F is placed.

G, the inner Tube or Drawer.

H, the outer Tube.

I, K, two braſs Rings which firmly bind or fix the ſame to the *Ball and Socket*.

L, the pipe of the inner Tube, on which is ſcrew'd

M, the Button containing the object Glaſs.

N, the part which holds the Microſcope, and is ſcrew'd on to

O, the Ball moveable every way in

P, the head of the Socket, placed and ſcrew'd on to

Q R, an upright Stem or Cylinder of wood, of a convenient ſize and height.

Q S, the ſcrew part thereof, on which moves

T, a Collar of wood or braſs, into

V, the neck thereof is ſcrewed,

W X Y Z, a Frame containing a parallelogram or long ſquare of Glaſs on which the objects are to be placed

W Y a b, is another frame moveable up and down on hinges under W Y and contains an oval reflecting mirrour c, for illuminating tranſparent objects on the glaſs plate above it.

This is the Structure of a Microſcope, which alone has the advantage of *univerſal*

uſe.

uſe. Here the microſcope may be placed in a *Perpendicular*, an *Oblique*, or an *Horizontal Poſition*, as occaſion requires. The object great or ſmall may here be viewed in any ſituation whatſoever without the incumbrance of a frame, the interruption of legs, and a limitted ſpace to act in: in this form are all the uſes of the common form, and many peculiar to itſelf.

For inſtance; a veſſel containing a young plant whoſe leaves ſpread horizontally, may be placed on the frame W Z, which may be raiſed or lower'd on the ſcrew Q S till it be at a proper diſtance from the object-glaſs, then may the veſſel or microſcope be moved this way and that till the end of the micrometer juſt touches the extremity of a leaf of the plant, in this poſture let all remain for the ſpace of twelve or twenty four hours, and then obſerve how many turns of the micrometer you make to adjuſt it again to the edge of the leaf; this will give you the parts of an inch it has grown in that time; and conſequently how much it grows in one hour, one minute, or one ſecond of time; or for any larger part of time. If you bring the microſcope to an horizontal poſition, you may then obſerve and meaſure the growth of almoſt any plant, or young tree, in height, in any propoſed time; eſpecially if it be confined within a glaſs tube; and I very much queſtion whether the *Circulation of the Sap* in ſome plants, and the *Circulation of the Blood* in ſome parts of the *human Body* be not diſcoverable by the microſcope mounted on the Ball and Socket; but theſe, and many ſuch like matters, I intend to give a more particular and certain account of e'er long.

A microſcope of the largeſt ſize will be beſt for this form, for tho' the *Power of Magnifying* in great and ſmall microſcopes be the ſame when the glaſſes are of the ſame focal diſtance reſpectively in each, yet ſince a large tube is capable of receiving a larger eye glaſs than a ſmall one; and not only that, but will better admit of two eye glaſſes, it will follow, that the *Field of the Microſcope*, or the extent of view therein will be larger, tho' the object will not be ſeen quite ſo clear and vivid as with one eye glaſs in a ſmall microſcope.

Microſcopes of more than *one Glaſs* are generally called *Double Microſcopes*, tho' very improperly; but the micrometer I think moſt proper for this larger microſcope, I may truly call a *Double Micrometer*, as conſiſting of two ſingle ones E and F, which are placed one on each ſide the tube diametrically oppoſite to each other.

Theſe, inſtead of having ſharp points as when uſed ſingly, are perfectly cylindrical, and their circular ends made to meet ſo very nicely, that when ſcrewed or ſet to-

gether

gether, they appear but one entire cylinder, and are to be uſed as follows.

The Micrometer E, which hath an *Index* moving by a circle graduated as before, is to be ſet to the beginning of the diviſions, viz. at 10, and at a proper diſtance from the plate; then the plate of Glaſs on which the object lies on the frame is to be moved this way and that, till the edge or the extremity of the object touch the end of the Micrometer E: This done, ſcrew the Micrometer F in or out till ſuch times as its end ſhall exactly touch the oppoſite extremity of the object. Then taking off the eye, turn the Micrometer E ſo often about till its end touches the end of the other Micrometer F, ſo ſhall the number of turns, and parts of a turn, give you the length of an object in the parts of an inch, as before taught.

In a *Microſcope* that has but one eye glaſs it is well known the *Micrometer* muſt be fixed in the *Focus* of that Glaſs; but in ſuch Microſcopes that have two eye glaſſes it may be asked where the *Micrometer* is then to be fixed? I anſwer, by the following rule it may be known.

Rule. (1.) Subſtract the *Diſtance* you propoſe to have between the two eye-glaſſes from the *Focal Diſtance* of the *leſſer-Glaſs*.

(2.) Multiply the *Remainder* by the *Focal*

Focal Diſtance of the *Greater Eye-Glaſs.*

(3.) Divide that product by the Sum of the ſaid *Remainder* and *Focal-Diſtance* of the *Greater-Glaſs*; the quotient will be the diſtance at which the *Micrometer* muſt be placed below the lowermoſt Glaſs.

Example 1. Let there be two eye-glaſſes, and the focal length of the greater be 3 inches, and that of the leſſer 2 inches; and let it be propoſed to fix them at one inch diſtance from each other. Then from 2 inches take 1 inch, the remainder is one, which multiply by 3 inches, the product is 3; this divided by 4, viz. the ſum of the remainder, and focal diſtance of the greater Glaſs, will quote 7 tenths of an inch for the diſtance of the Micrometer required, below the loweſt eye-glaſs.

Example 2. Suppoſe the focal diſtance of the greater eye-glaſs be 3 inches, and of the leſſer 1 inch and a half, and they are placed at 2 inches diſtance from each other; then will the focus of the upper eye-glaſs fall between the two glaſſes, as being ſhorter than their diſtance from each other; and therefore the Micrometer muſt be here fixed between the ſaid eye-glaſſes, viz in the focus of the upper one. And this I recommend as the beſt way of the two.

Now ſince in theſe large Microſcopes there are generally 4 or 5 object glaſſes, the ſmalleſt diviſions on the circle of the Micrometer will be ſo many parts of *one thouſandth part of an inch*, as the diſtance of the object is contain'd times in the diſtance of the image, from the object lens, that is uſed. Thus if the diſtance of the object be contained 4, 6, 8, 10, 12, &c. times in the diſtance of the image; each of thoſe diviſions will be a 4000dth, 6000dth, 8000dth, 10000dth, 12000dth, &c. part of an inch.

The diſtance of the image from any object lens is known thus; take the *Focal Diſtance* of the lens by the ſun beams, if it be a double convex, and then meaſure the diſtance of the object (in the microſcpe, when you ſee the image plain) from the ſaid lens; multiply theſe together, and divide the product by the difference of thoſe diſtances, the quotient will be the diſtance of the image.

Example.

Let the focal diſtance be ,5 ,6
Diſtance of the object ,6 ,5
Product ,30 ,1 the difference.
Then ,1)30(3 inches, the diſtance of
,30
—
. .

the image, which is 5 times ,6 the diſtance of the object; and therefore the diviſions on the Micrometer will in ſuch a caſe be the 5000dth parts of an inch.

The power of magnifying is computed in the ſame manner as in the ſmaller Microſcopes, when you have found the focus by the rule above, which needs not be here again repeated.

The Method of computing the Power of MAGNIFYING, and of MEASURING the *Heavenly Bodies* by the MICROMETER in a TELESCOPE.

IN Fig. V. Let A C B be the object-glaſs of a Teleſcope; F its Focus; D E the eye glaſs whoſe focus is alſo in the point F.

Suppoſe this Teleſcope be directed to any of the Heavenly Bodies, as the *Sun* for inſtance; the rays falling parallel on the glaſs A B will be united in the focus F, and there form the image of the Sun G H. This image is ſeen under the ſame angle G C H as the Sun itſelf would appear under to an eye at C. It is alſo ſeen by an eye at the eye-glaſs D E under the angle G I H. The magnitude of the Sun will therefore be to the naked eye at C in proportion to its magnitude as ſeen by the eye-glaſs D E, as the angle G C H to the angle G I H; that is, in ſuch ſmall angles, as the diſtance I F to the diſtance F C, viz. As the focal length of the eye-glaſs to the focal length of the object-glaſs. Suppoſe then the focal diſtance C F of the object-glaſs be 4 feet or 48 inches, and that of the eye-glaſs I F be 2 inches. In this caſe, ſince C F is 24 times greater than I F, the diameter of the ſun will be magnified 24 times; its *Surfaces* 576 times, and its *Solidity* 13824 times, in this Teleſcope.

Again, ſuppoſe the focal length of the object-glaſs, be 12 foot, or 144 inches; and that of the eye glaſs be 2 inches and a half. Then ſince, in this caſe C F is almoſt 58 times greater than I F, therefore the *Diameter* of the Sun will be magnified 58 times nearly, the *Surface* thereof 3317 times, and the *Solidity* 191103 times. The bodies of the Sun, Moon and Planets being magnified to ſuch a great degree, muſt needs appear very large thro' ſuch a Teleſcope.

Laſtly, if the eye-glaſs D E be a *Concave* one, whoſe focal diſtance is one inch; and the object-glaſs 3 feet focus, or 36 inches; then ſhall the *Diameter* of the Sun or Planets be enlarged 36 times; their *ſurface* 1296 times, and their *bulks* 46656 times. Such a Teleſcope as this may be had very cheap, will take up little room, and yet will have ſo great a power of magnifying, that the *ſpots* in the Sun, the *inequalities* of the Moon's ſurface, the *Phaſes* of Venus, and the *Satellites* of Jupiter if not the *Ring* of Saturn, may be plainly viewed therewith.

The double Micrometer K G, L H is fixed in that part of the tube of the Teleſcope where the image is formed, in the focus of both the Glaſſes H F G.

Suppoſe the focal length C F of the object glaſs, be 12 feet or 144 inches, and let the diſtance from G to H be half an inch; then will F G be a quarter of an inch, and therefore in the right angled triangle F C G, there being given the two ſides C F 144 inches, and F G a quarter of an inch, we ſhall find by the rules of Trigonometry, that the quantity of the ſmall angle F C G, will be 5 minutes, 58 ſeconds, and 16 thirds; the whole angle G C H will therefore be 11 minutes, 56 ſeconds, and 32 thirds, or 42992 thirds; if then the Micrometer contains 50 threads in an inch; there will be 25 in half an inch, then dividing 42992 thirds by 25, the quotient will be 1719 thirds, which is 28 ſeconds, and 39 thirds for every turn or revolution of the index of this micrometer.

On the face of the micrometer is a circle divided into 10 equal parts, and each of theſe ſubdivided into 10 others; ſo that the whole contains 100 equal parts. Thus every 10th part meaſures 172 thirds, or 2 ſeconds and 52 thirds; and every 100th part, 17 thirds of a degree; which is to ſo

great

great a nicety, that nothing beyond it can be requir'd.

The way of uſing this double micrometer here is the ſame as before taught in the *univerſal Microſcope*, but ſomewhat more difficult; for in the Microſcope the ſubject to to be meaſured is quieſcent or motionleſs; but the motion of the Heavenly Bodies is ſo ſenſible while you are meaſuring them, that you can't ſo eaſily adjuſt the micrometers to the extremities of their bodies.

INSTRUCTIONS for rightly uſing the MICROSCOPE, TELESCOPE, &c.

WHEN you would view any object thro' theſe inſtruments, take out the glaſſes carefully, and cleanſe them from duſt, &c. by wiping them in a piece of ſoft leather, fine linnen, or ſilk, doubled over the glaſſes.

In putting them in again, hold them by the edges, and let not your fingers touch the ſurface, eſpecially the middle part of the Glaſs; for the cleaneſt fingers will ſully them, and make the object appear miſty or obſcure.

In placing the glaſſes take care alſo that they lie horizontally, or even on every part; for if they lie on one part higher than the other, they will a little diſtort and diſcolour the object.

In ſetting a Microſcope to a true focus (as we vulgarly term it,) place the left hand on the outer tube, and holding it faſt and ſteady, with the right hand ſlide the inner tube up and down till the object appears moſt plain, and there let it remain for uſe.

If a By-ſtander would view the object, he ought to ſet the Microſcope (as directed) for himſelf; for the focus that ſuits one perſon's eye, may not very often fit anothers.

When the Microſcope is ſet true, the object will appear extremely clear, diſtinct and perfect; if it does not thus appear we muſt conclude the tube is not well adjuſted.

Place the eye in viewing, juſt over the middle of the aperture or hole of the Microſcope, moving it a little up and down till you hit on the place where you have the cleareſt and largeſt view.

In placing the object, take care that the part you would view be placed as near as poſſible in the center of the view; for thoſe parts which lie near the ſides, appear colour'd and miſhapen by the refraction of the glaſſes.

Let the object be ſo placed, that the part propoſed to be viewed, may have the ſtrongeſt light; at leaſt, that it may be well enlightened.

Let tranſparent objects be laid on a long ſlip of clear glaſs, that ſo the object may be moved with the glaſs, and *not by itſelf on the glaſs*, as has been the *uſual way*.

Let the reflecting mirrour be moved up and down till the object receives that quantity and colour of light as will ſhew it to the beſt advantage.

A red light is beſt for tranſparent bodies of a darkiſh hue; a white light for blue, yellow, green, red, &c. colours; and a pale or watry light for greyiſh and white ſubjects.

In dark or opake bodies, the reflecter ſhould be ſhut up in the Pocket Microſcope; for light in this caſe generally does more harm than good.

I need not ſay, that of opake bodies, the black ones require the greateſt light, and the white ones, the leaſt.

The light of the meridian Sun is too ſtrong and ſparkling, for any but ſmall objects; or when the aperture of the object-glaſs button is very ſmall.

Yet when we view extremely ſmall objects, the object glaſs is ſo very near the object and takes in ſo ſmall a part, that 'tis neceſſary to illuminate it with the ſun's rays collected by a convex lens held in the hand.

In viewing extremely ſmall objects, the hole in the button of the object glaſs ſhould be very ſmall, to exclude all rays but thoſe which come from a point in the object directly under it.

The ſmaller the hole in the button is, the leſſer will be the light; and therefore if this hole be too ſmall, the object will appear too obſcurely; if it be too large, it will make the object confuſed and indiſtinct by too much light. Therefore it may, in ſome caſes, be neceſſary to uſe a ſmall circular piece of braſs fitted to the cavity of the button, with a hole perforated in the middle, of ſuch a ſize as is requiſite to make the object appear viſible and diſtinct.

Laſtly, take ſpecial care that your breath do not fall on the glaſſes while you are uſing the microſcope, and that you hold not your warm hand long on the part where the eye-glaſſes lie; for by this means the glaſſes will become dewy, the object obſcured, and you'll have the trouble of taking the microſcope to pieces to rectify what is amiſs.

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APPENDIX.

THE Conſtruction I firſt propoſed for my Pocket Microſcope, was with a ſingle Eye-Glaſs, in regard to the uſe of the Micrometer; which is much eaſier underſtood in that, than in one more compounded with Eye-Glaſſes.

It was not long before I was convinced I was in an error; for when I expoſed my microſcopes to ſale, I found that the generality of people, choſe them rather without the micrometer, than with it, as not underſtanding that inſtrument; and therefore as thoſe who underſtood and choſe them with micrometers, knew their uſe in any conſtruction, and thoſe who did not, would be much better pleaſed with two Eye-Glaſſes than one, as it affords a much larger field of view, or extent of ſight, in the microſcope, I ſoon ſaw it convenient to have them all made with two Eye-Glaſſes. And thus they have all the eſſential parts of the largeſt and beſt compound microſcopes ever made.

In many of my firſt microſcopes, I fixed the micrometer below both the Eye-Glaſſes, but I ſaw reaſon for alteration in that reſpect likewiſe; for tho' the micrometer in that poſition will meaſure an object as well as in any, yet on ſome accounts, I now chuſe to place it between the two Eye-Glaſſes, viz. in the focus of the uppermoſt Lens; and its uſe here is as eaſy to be underſtood by thoſe who know the theory, as before. This is the preſent form and conſtruction of the Pocket-microſcope, as I now make them, with the braſs micrometer; and a better than this I believe the nature of the thing will not admit.

But as many perſons who do not underſtand the nature of the Screw-micrometer, would, doubtleſs be glad to have it in their power by ſome means or other, to make a proper and near eſtimate of the ſize or dimenſions of the objects they view, ſo I have endeavoured to accommodate them with an inſtrument that will give them entire ſatisfaction in this particular; for by this means they will be able to gueſs at the length or breadth of an object, with ſuch certainty as not to be out *one thouſandth part of an inch.*

The inſtrument I mean, is only a circular piece of glaſs, with parallel lines running along the middle of it, diſtant from each other the fortieth part of an inch; that is, forty of thoſe ſpaces are exactly equal to an Inch. Theſe lines I draw with great exactneſs by a machine I contrived for that purpoſe. And ſince I ſhall ſhew by this piece of glaſs the magnitude of ſmall objects may be very well determined, I shall take the liberty of calling it, *The Glaſs Micrometer*.

Now in the microſcopes which have this Glaſs-micrometer, the two Eye-glaſſes are ſo diſpoſed, that the under glaſs is placed juſt in the focus of the upper one; and therefore when an object is to be meaſured you need only take the glaſs-micrometer and lay it on the ſaid undermoſt Lens, and then ſetting the microſcope right for view, you will ſee the image of the object form'd upon, and lying among the parallel lines of the micrometer.

And then it will be eaſy to judge of the true dimenſions of objects in the manner following. Firſt, Compute the power of magnifying, thus; lay a ruler with inches divided into *tenth Parts* under the microſcope, and count how many of theſe parallel ſpaces on the micrometer fall on the ſpace of one tenth of an inch; then a 4th part of that number shews the power of magnifying. Thus if twenty of thoſe ſpaces exactly equal the tenth of an inch in the microſcope, then a 4th part, viz. 5, is the power of magnifying; that is, the image is in this caſe 5 times larger than the object.

Secondly, This being once known, then 'tis evident, that ſince one of the ſpaces on the micrometer is equal to, or meaſures the 40th part of an inch in the image, it will meaſure a part in the object, which is juſt the 200dth part of an inch. And therefore, half one of theſe ſpaces will meaſure a 400dth part; a quarter will meaſure an 800dth part; and a fifth will meaſure the 1000dth part of an inch in an object.

Thirdly, Now the upper Eye Glaſs will ſufficiently magnify theſe ſpaces on the micrometer, to enable the eye to diſcern a tenth part of one of theſe ſpaces diſtinctly; and therefore a 5th part with great eaſe, which, as I ſaid, will be ſufficient to meaſure the 1000dth part of an inch.

Fourthly, When therefore you would meaſure an object, or part of it, you muſt move the inner tube of the microſcope about this way and that, till the ſpaces of the micrometer lie parallel over, and ſome one line touch one extremity of the part to be meaſured, then you will ſee how many of thoſe ſpaces and parts of a ſpace are occupied by the length or breadth thereof; and ſo be able to know what part of inch it is in the manner abovementioned. And the method is the ſame, be the power of magnifying what it will. And I will be bold to ſay, that if theſe micrometers are not ſufficiently eaſy to be underſtood, I believe none will be ever found to be ſo, that have any tollerable degree of exactneſs and certainty.

It has been ſuggeſted to me, that ſeveral who has bought theſe microſcopes, do not know how to uſe them without ſome further directions; this I look upon as very wonderful, conſidering the great ſimplicity of the ſtructure of this microſcope, and the reſemblance it bears to thoſe of moſt common uſe. I could never have thought that the nature and uſe of the microſcope (ſo exceeding curious and uſeful an inſtrument) had been ſo little underſtood at this time of day, in a land of ſo much Knowledge as *England*, that any difficulties could ariſe concerning the uſe of the *Pocket Microſcope*, whoſe nature, conſtruction and uſe are and muſt be allowed the moſt obvious, ſimple and eaſy of all others yet invented.

However, that nothing may poſſibly diſcourage the inquiſitive, I ſhall add to the former directions, thoſe which follow.

If the object be opake, or not tranſparent, the bottom of the microſcope is not to be let down; for the light reflected from the mirrour, will in that caſe do much harm.

If the object be tranſparent, then you muſt let down the braſs bottom, holding the tube faſt with the hinder part in the palm of the left hand, while the right hand moves the inner tube up and down, till the object appears very plain.

Then taking the microſcope in the right hand, you move the reflecting mirrour up and down, till you find the beſt light for ſhewing the object to the beſt advantage.

Take care that the microſcope be held perpendicular, or down-right, not ſlaunting; for then will the object be apt to roll out of ſight, or off from the inſtrument.

Never attempt to view an object in any but a very lightſome room, or in the open air; and hold the inſtrument towards that part of the heavens where the ſun is, yet not ſo as to receive his beams too fully. A very cloudy, dark air, or gloomy room, will always defeat your purpoſes, and make you have an ill opinion of the inſtrument without cauſe.

In the laſt place, take care that your hand, fingers, or any other object do not obſtruct the light from falling directly on the aperture of the microſcope, for then will the object you view be ſo obſcured, that you cannot ſee it diſtinctly.

I cannot think of any other caution, but what common ſenſe muſt ſuggeſt to every man that has the leaſt notion of a microſcope; and believe theſe I have now given, together with the former, are fully ſufficient for an inſtrument, whoſe very form plainly indicates its caſy manner of uſe.

12 JY 64

Juſt Publiſhed,

Dedicated to the ROYAL SOCIETY.

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OR THE

Knowledge of the Heavens and the Earth Diſplay'd.

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The MICROSCOPIC CANE

Fig: III

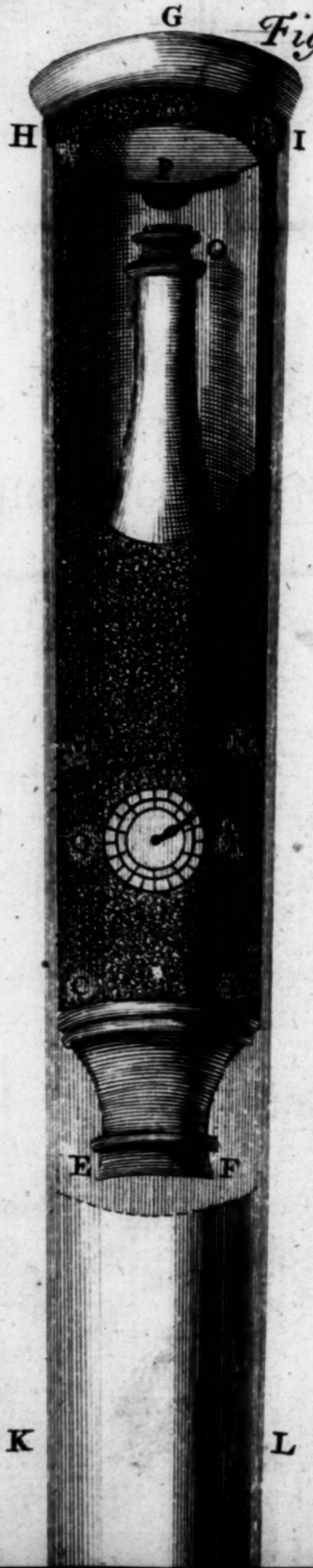


Fig: IV.

The *UNIVERSAL* MICROSCOPE

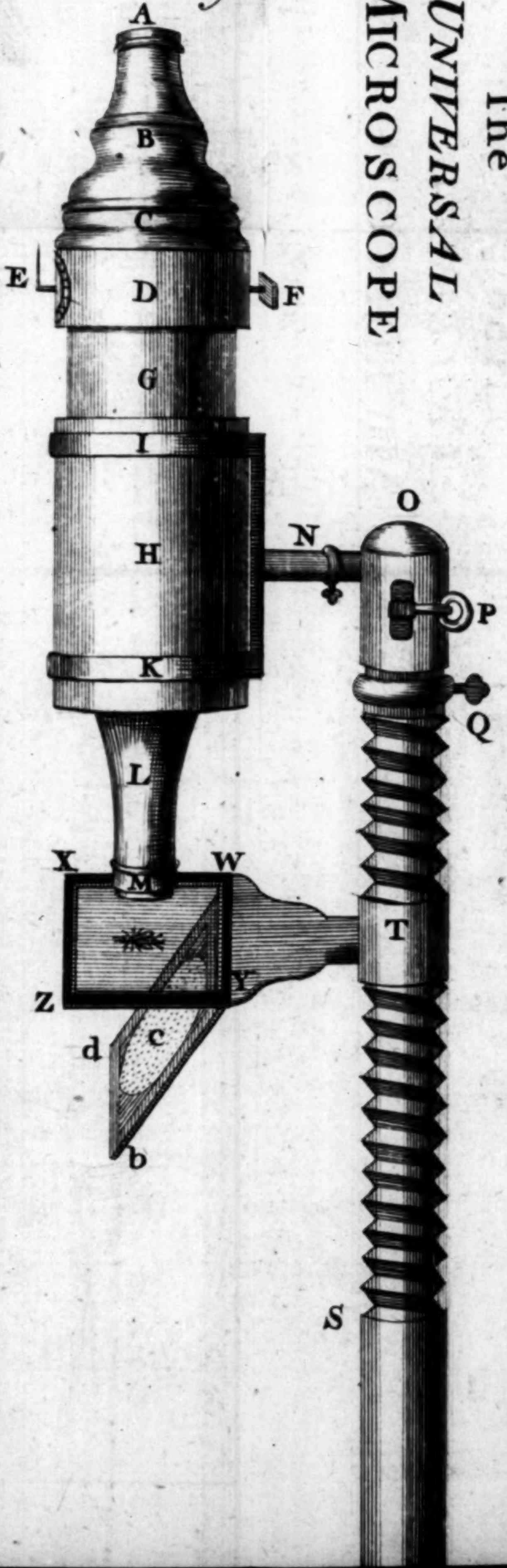
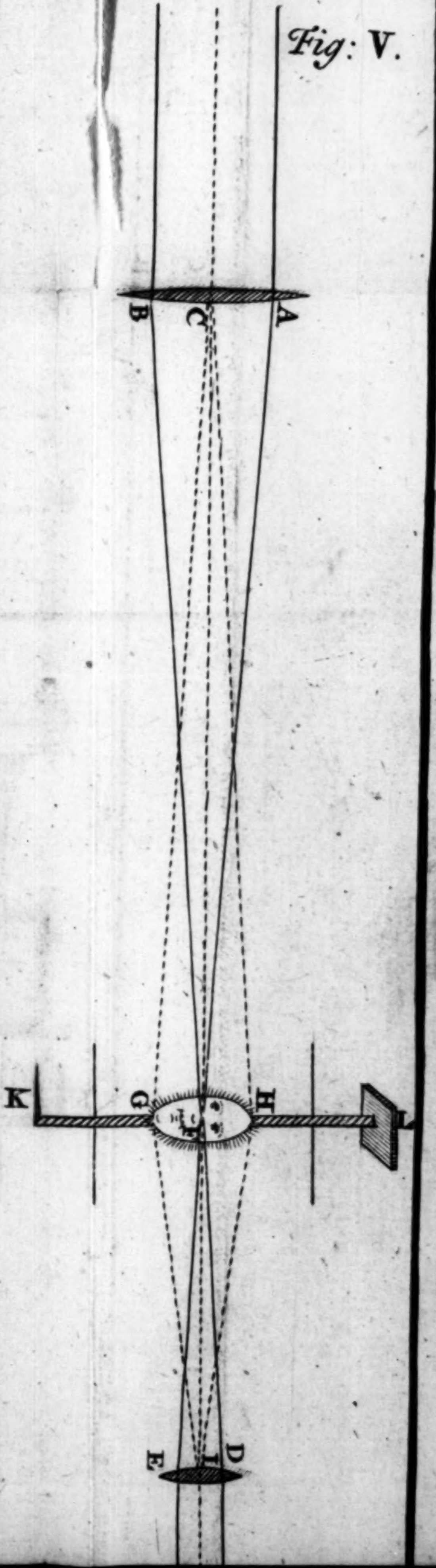
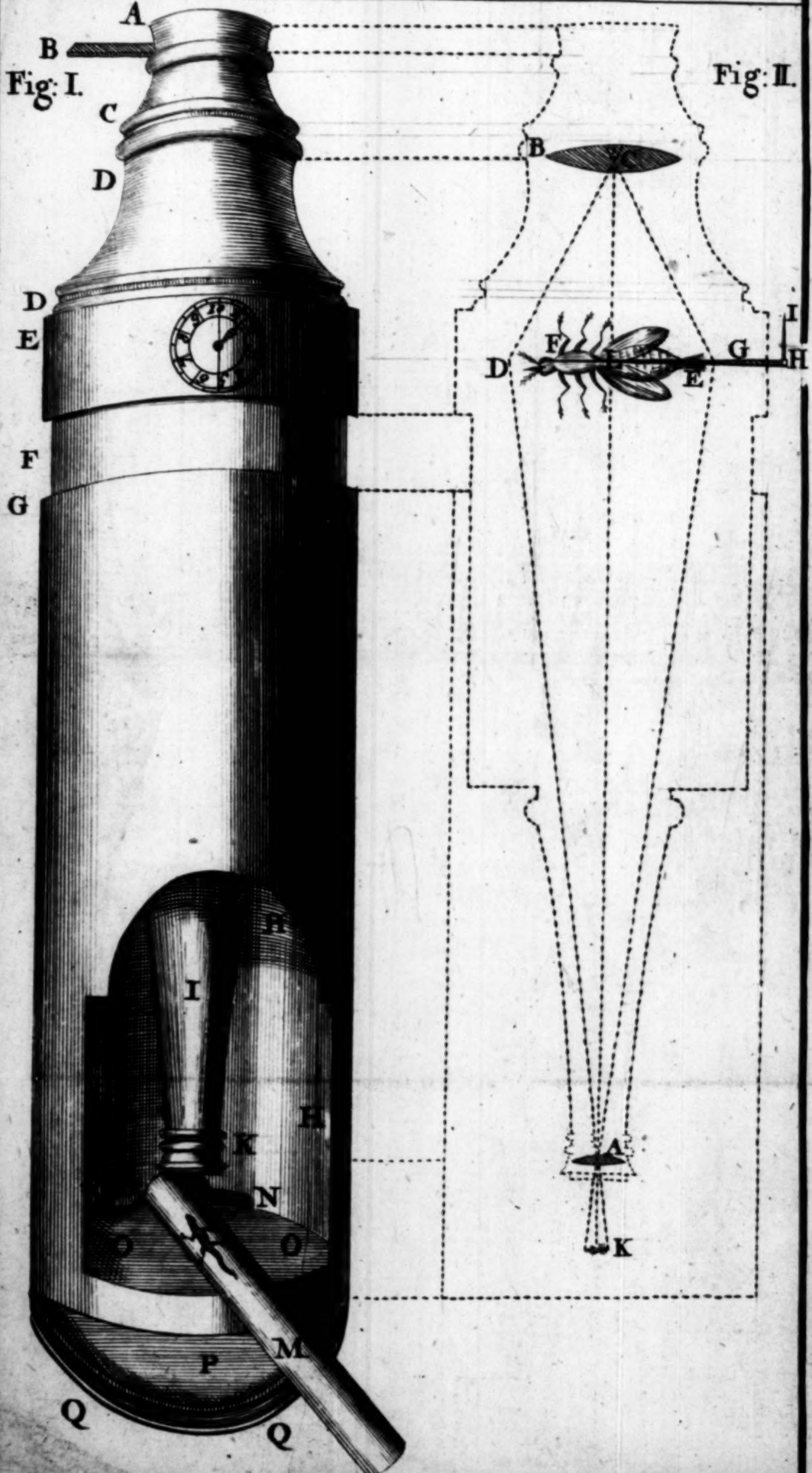


Fig: V.



The POCKET REFLECTING MICROSCOPE with a MICROMETER.



E.Bowen Sculp.